

DIRECTED FORGETTING OF ELEMENTS IN
COMPOUND SAMPLES

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Pigeons were trained in a delayed matching-to-sample procedure in which the sample stimuli consisted of a compound of color (red or green) and spatial location (left or right). A postsample cue (houcelight on or off) signaled whether color matching or location matching would be required following the delay. In Experiment 1, the reduction in performance on probe trials (in which the houcelight condition was reversed relative to that on regular trials) was greater for location matching than for color matching. The birds showed overt mediational behavior during the delays on location-matching trials. On color-matching trials, the birds exhibited behavior during delays that might have interfered with that mediational behavior. In Experiment 2, the houcelight condition was changed shortly before presentation of the comparison stimuli on probe trials. Accuracy of location matching was reduced when the cue initially signaled color matching and was then changed to signal location matching, whereas matching accuracy was not reduced by a change in the opposite direction. Accuracy of color matching was reduced by a change in illumination level from dark to light, regardless of type of the relevant dimension signaled by houcelight illumination. Discussion of these findings focuses on the variables critical to establishment of an effective cue to forget.

Key words: nonhuman memory, directed forgetting, delayed matching to sample, delay behavior, mediational behavior, compound stimulus, key peck, pigeons

Stimulus control of forgetting in nonhuman working memory has been investigated using a version of the delayed matching-to-sample task that is analogous to the directed forgetting techniques commonly used in the study of humans (e.g., Bjork, 1972). In the typical directed forgetting experiment, termination of the sample stimulus is followed by a remember cue (R cue) or a forget cue (F cue). A trial terminates with the usual comparison phase on R-cued trials, whereas the comparison phase is omitted on F-cued trials. In the comparison-omission procedure, matching accuracy is reduced on infrequent probe trials in which the comparison stimuli are presented following an F cue (Maki & Hegvik, 1980; Santi & Savich, 1985; Stonebraker & Rilling, 1981; Stonebraker, Rilling, & Kendrick, 1981). The best supported theoretical interpretation of this finding is the rehearsal-termination hypothesis. This hypothesis states that information derived from the sample stimulus is actively maintained in working memory by rehearsal, and that an F cue terminates this rehearsal.

In the comparison-omission procedure, however, R- and F-cued trials differ at least in three ways. The cues signal differential opportunities for reinforcement, differential opportunities for choice responding, and differential control of choice responding by the sample stimuli (i.e., relevance or irrelevance of the sample stimuli to choice responding). Hence, variables critical to the cuing effect have not been well specified. This concern led to a second methodological refinement: the comparison-substitution procedure, in which discriminative or nondiscriminative stimuli are substituted for the usual comparison stimuli at the end of the delay on F-cued trials.

Grant (1981) presented a dot in place of the usual test stimulus (either a red or green field) on F-cued trials in a successive delayed matching-to-sample task with red and green fields as the sample stimuli. Pecks at the dot were ineffective, and 5-s presentation of the dot was followed by noncontingent (response-independent) reinforcement on 50% of F-cued trials. Because reinforcement was delivered on 50% of R-cued trials (i.e., matching trials), the F and R cues signaled *nondifferential* opportunities for reinforced responding but *differential* control of responding by the sample stimuli. The discrimination ratio was reduced on F-cued probe trials, just as in the comparison-omission procedure. Grant (1981) argued that

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a sufficient condition for establishing an effective forget cue is that the cue signals the irrelevance of the sample stimulus. Recently, Grant and Barnet (1991) obtained results supporting this notion by using a successive matching procedure in which an F cue was followed by sample-independent discriminative stimuli.

However, other investigators who used a simultaneous choice matching procedure have found that the cuing effect was largely eliminated when F-cued trials terminated with an irrelevant (i.e., sample-independent) discrimination (Kendrick, Rilling, & Stonebraker, 1981; Maki & Hegvik, 1980), with reinforced nondiscriminative responding (Maki, Olson, & Rego, 1981), or with response-independent reinforcement (Kendrick *et al.*, 1981). Maki (1981) suggested that omission of end-of-trial reinforcement, rather than the irrelevance of the sample stimuli, is the critical factor for producing the cuing effect in the comparison-omission procedure. Kendrick *et al.* (1981) argued that because probe performance was poor when F and R cues controlled different types of end-of-delay behavior but was good when they generated similar types of end-of-delay behavior, performance decrement on probe trials was due to the absence of a behavioral context necessary for retrieval of the sample memory (the behavior-context hypothesis). This notion is consistent with the observations in earlier directed forgetting studies that pigeons pecked the sample key throughout the delay interval on both R- and F-cued trials when reinforcement occurred at the end of both types of trial (the comparison-substitution procedure), but that pecking occurred only on R-cued trials when F-cued trials ended with no reinforcement (the comparison-omission procedure). More recently, Rilling, Kendrick, and Stonebraker (1984) suggested that an F cue will gain control over forgetting only when that cue is presented on trials that do not require attention to subsequent events and stimuli on that trial (the attention hypothesis).

In the comparison-substitution procedure, R- and F-cued trials still differ in two ways. First, the sample stimuli are relevant to choice responding on R-cued trials, but they are irrelevant on F-cued trials. Second, delayed responding is required on R-cued trials, whereas F-cued trials never end with delayed respond-

ing. Thus, differential control by the sample stimuli is confounded with differential opportunity for delayed responding. For a proper test of the rehearsal-termination hypothesis, overall task requirements on both R- and F-cued trials should be the same in all respects except for differential control by the sample stimuli.

The present experiments devised a new procedure in which differential control by the sample stimuli was not confounded with other variables. Pigeons were trained in a modified delayed matching-to-sample procedure in which a single sample stimulus contained both color and spatial-location information by virtue of its color (red and green) and key location (right and left). Following a delay, during which a cue signaling the relevant component was presented, the birds were tested on the color dimension by presenting red and green comparisons (color-matching trials) or on the spatial-location dimension by presenting yellow right and yellow left comparisons (location-matching trials). Thus, color-matching trials and location-matching trials did not differ in the overall task requirement but differed only in the relation between the sample stimuli and reinforced choice responding. The question of interest was whether an instructional cue would come to function as an effective cue to forget the irrelevant element of the compound sample.

EXPERIMENT 1

In Experiment 1, the cue signaling whether color matching or location matching was required in the choice phase was houselight illumination during the delay interval. To counterbalance the potentially interfering effect of houselight illumination on accuracy with color- and location-matching tasks, houselight-on signaled color matching and houselight-off signaled location matching for 2 birds, and houselight-off signaled color matching and houselight-on signaled location matching for the other 2 birds.

METHOD

Subjects

Four experimentally naive pigeons were maintained at approximately 80% of their free-feeding weights. Birds were housed individu-

ally and had free access to grit and water in their home cages.

Apparatus

A three-key experimental chamber (33.5 cm long, 28.0 cm wide, and 35.5 cm high) was placed in a sound- and light-attenuating outer shell fitted with a ventilation fan. The front panel of the chamber contained three translucent plastic response keys, 2 cm in diameter and 5 cm apart center to center. Approximately 15 cm directly below the center key, an aperture (7 cm wide and 6.5 cm high) allowed access to a mixed grain feeder (Gerbrands). The aperture was illuminated during reinforcement. Three miniature 28-V color lamps (TechServ) mounted behind each key could illuminate the keys with red, green, or yellow light. A 28-V bulb, centered in the ceiling, served as the houselight.

A window (30 cm wide and 15 cm high) on a wall of the outer shell allowed periodic observation of the birds via a videocamera (National, VY-4800). A microcomputer system (NEC, PC-9801 VX4) controlled experimental events and recorded responses.

Procedure

All birds were magazine trained, successive approximations to a key-pecking response were reinforced, and at least three sessions were given in which 60 reinforcers were provided on a schedule of continuous reinforcement. In subsequent training, houselight-off signaled color matching and houselight-on signaled location matching for Bird 1 and Bird 4. For Bird 2 and Bird 3, houselight-on signaled color matching and houselight-off signaled location matching.

During the first training phase, all 4 birds were trained to match red and green comparisons to the sample stimuli. A session consisted of 60 color-matching trials. A trial began with the houselight on and the right, center, or left key illuminated red or green. The fifth response extinguished the sample stimulus and initiated a 1-s delay, during which the houselight was extinguished for Birds 1 and 4 or illuminated for Birds 2 and 3. After termination of the delay, the keys other than the one on which the sample stimulus had been presented were illuminated with red and green as comparison stimuli. Hence, the choice of

comparison stimulus could not be influenced consistently by competition from the sample location. A single peck to the comparison stimulus that matched the sample color was reinforced with 3-s access to grain, and a single peck to the nonmatching comparison produced a 3-s timeout with the houselight off. Following an incorrect response, the same trial was repeated until the bird responded correctly. The intertrial interval was 20 s with the houselight off. The houselight was turned on when the sample or comparison stimuli were presented. Each of the 12 different combinations of sample color, sample location, and position of the comparison stimuli ($2 \times 3 \times 2$) occurred on five trials within a session. Each bird was trained until it reached a criterion of 80% correct choices or better in two successive daily sessions.

When a bird had achieved criterion performance on the color-matching problem, it began training on the location-matching problem in half of each daily session. The remaining trials in each session were color-matching trials identical to those in the first training phase. On location-matching trials, the red or green light was presented on either the left or right side key. Following a 1-s delay, during which the houselight was illuminated for Birds 1 and 4 or extinguished for Birds 2 and 3, yellow light was presented on the two side keys as comparison stimuli. Competition from the sample color could not occur because red and green were not presented as choice alternatives. A single peck to the yellow key that occupied the same location as the sample was reinforced, whereas a peck to the other yellow key produced a timeout. Combinations of sample location and its color provided four possible types of location trials. Other procedural details were the same as for color-matching trials.

The sample stimulus presented on the center key uniquely predicted a correct response prior to the delay, because the center sample appeared on color-matching trials but not on location-matching trials. On trials in which the sample stimulus was presented on the left or right key, matching of color or location of the compound sample depended on the status of the instructional cue in the delay interval.

Of 60 trials, the first 12 trials consisted of six color-matching trials and six location-matching trials. The following 48 trials con-

sisted of two randomized blocks of 24 trials. Within each block, each of 12 types of color-matching trial occurred once and each of four types of location-matching trial occurred three times, respectively. Each of four quasi-random sequences of 60 trials was used once for 4 days; these sequences allowed each type of color-matching or location-matching trial to occur equally often across two successive daily sessions. Within each sequence, the same dimension (color or location) was not tested on more than three consecutive trials, and the same position of correct comparison did not appear more than three times in succession. Each bird was trained until it reached a criterion of 80% correct choices or better on both color- and location-matching trials for two successive sessions.

During the next training phase, the initial 1-s delay was incremented by 1 s upon the completion of the 80% criterion. The maximum delay at which matching accuracy of more than 80% was maintained was determined for each bird. With the resulting maximum delay, each bird was given sessions in the same way as in the previous training except that the correction procedure was not employed. Training was continued until each bird reached the 80% criterion for two successive sessions.

Probe testing was then conducted with the maximum delay interval on days when the bird's performance was greater than 80% correct in the first 12 trials. If the criterion was not reached, probe testing did not occur in the following 48 trials and the session was recorded as a training session. Probe sessions were identical to the baseline sessions except that six of the last 48 trials were probes in which the houselight condition during the delay was reversed relative to that on regular trials. For Birds 1 and 4, a dark delay interval was followed by the yellow comparisons and an illuminated delay interval by the red and green comparisons. For Birds 2 and 3, an illuminated delay interval was followed by the yellow comparisons and a dark delay interval by the red and green comparisons. A correct choice was reinforced, whereas an incorrect choice immediately began the intertrial interval. Three of the six probes were color-matching trials and the remainder were location-matching trials. The probe trials did not appear more than once in succession. Each of the 12 types of color-matching probes was tested twice, and each of the four types of location-

matching probes was tested six times. A particular type of probe was not tested more than once per session.

RESULTS

Performance on color-matching trials dropped when location-matching trials were introduced. The birds performed relatively accurately on location-matching trials from the beginning of the baseline training, and additional sessions were needed for the birds to recover performance on color-matching trials. Birds 1 and 4 received 48 and 44 sessions, respectively. Birds 2 and 3 received 80 and 127 sessions, respectively. The resulting maximum delay was 3 s for Birds 1 and 4 and 2 s for Birds 2 and 3.

Figure 1 shows the percentage of correct matches in probe sessions for each bird as a function of trial type. Probe performance decreased on both color- and location-matching trials, relative to the performance on regular trials conducted within the same session. The reduction in performance was larger on location-matching trials than on color-matching trials. Mean accuracy on probe trials across 4 birds as a percentage of accuracy on regular trials was 51.9% (range, 45.8% to 55.5%) for location matching and 71.4% (range, 50.8% to 81.3%) for color matching. A three-way analysis of variance with illumination condition (Birds 1 and 4 vs. Birds 2 and 3), dimension tested (color vs. location), and trial type (regular trials vs. probe trials) was conducted on the arcsine-transformed percentage scores (the transformed scores were used in all analyses involving percentages). The factor of illumination condition was treated as a between-groups effect, and the other two factors were within-subject effects. Significant effects were found for trial type, $F(1, 2) = 70.8$, $p = .01$, and the interaction of trial type with dimension tested, $F(1, 2) = 86.6$, $p = .01$. The interaction confirms the asymmetrical cuing effect on color and location dimensions. The effect of illumination condition, $F(1, 2) < 1$, dimension tested, $F(1, 2) = 3.7$, $p = .20$, and all other interactions involving illumination condition, trial type, and dimension tested did not reach statistical significance. The nonsignificant effect of illumination condition and the nonsignificant interactions of illumination condition with other factors mean that the data for Birds 1 and 4 can be combined with those of Birds 2 and 3. That is, the status of the houselight

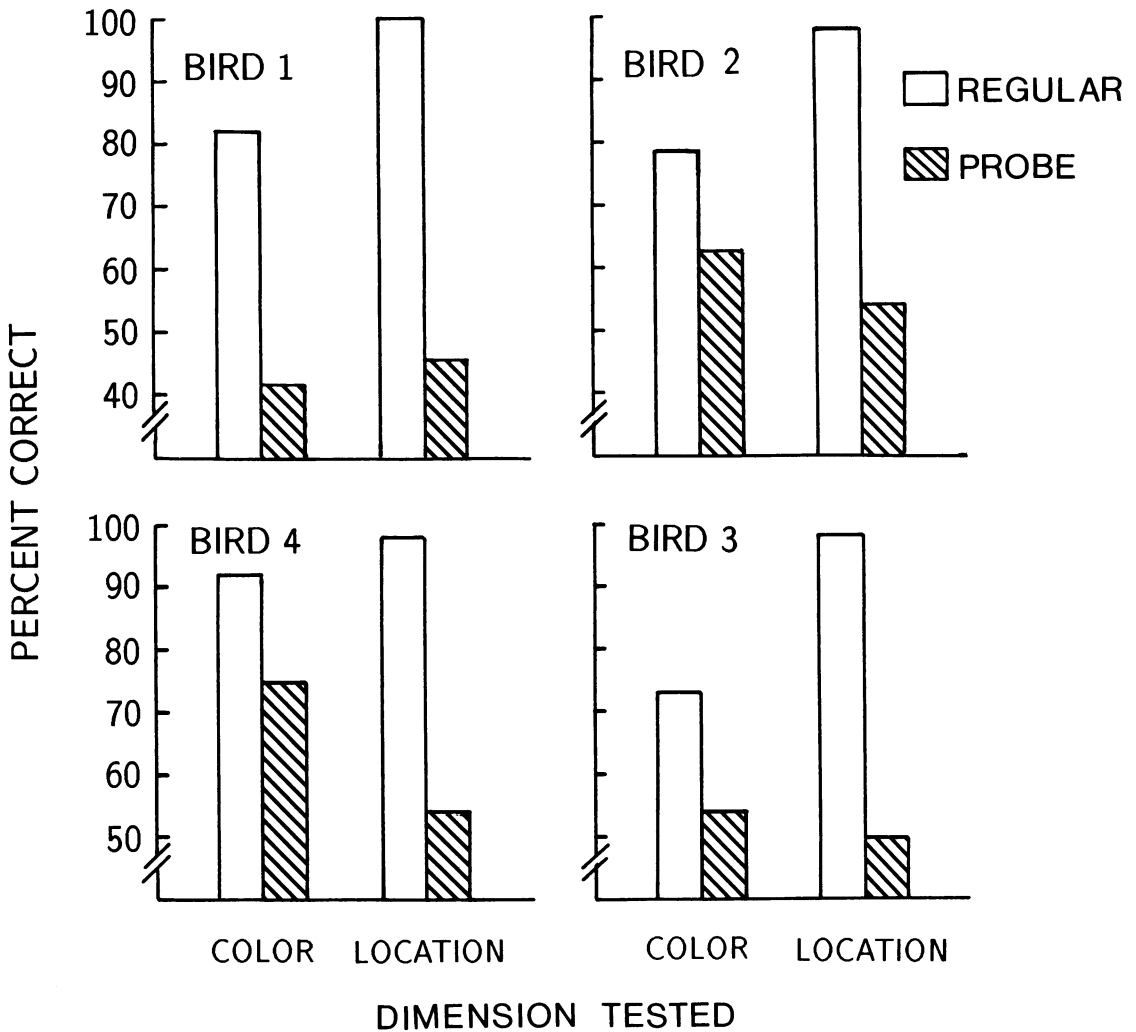


Fig. 1. Percentage of correct matching over 168 regular trials (open bars) and 24 probe trials (hatched bars) following training in which houselight-off signaled color matching and houselight-on signaled location matching (Birds 1 and 4) or following training in which houselight-on signaled color matching and houselight-off signaled location matching (Birds 2 and 3).

illumination signaling color and location matching did not differently affect the reduction in performance on probe trials.

Accuracy of color matching was analyzed separately for the probe trials in which a sample was presented on the center key (center-sample trials), a sample was presented on either the right or left key with a correct comparison on the center key (center-correct trials), and a sample was presented on either the right or left key with a correct comparison on the side key on which the sample had not been presented (side-correct trials). Mean ac-

curacy across the 4 birds was 53.1%, 68.8%, and 53.1% for center-sample, center-correct, and side-correct trials, respectively.

DISCUSSION

The present experiment was designed to determine whether a postsample stimulus functions as an effective cue to forget under a condition that eliminates differential opportunities for reinforcement and differential opportunities for delayed choice responding. In particular, interest focused on whether the irrelevance of the sample to choice responding

or absence of the opportunity for delayed responding is critical to the establishment of an effective cue to forget. The question stemmed from the fact that neither the standard omission procedure nor any of the substitution procedures in the previous studies provided an opportunity for sample-dependent delayed responding on F-cued trials. It is possible, therefore, that the critical variable that results in the establishment of an effective cue to forget is not that the sample is irrelevant to choice responding on F-cued trials but rather that delayed responding, which necessarily involves memory-related processes, is not required. In the present experiment, delayed responding and reinforcement for a correct choice were guaranteed to end all trials so that the postsample cues were correlated only with the dimensions required to match the sample stimulus in the upcoming choice phase. The finding that matching accuracy was reduced on incorrectly cued probe trials demonstrates that the irrelevance is a critical condition to the establishment of an effective cue to forget.

Reduction in probe performance was greater for location matching than for color matching. This asymmetrical cuing effect was not due to differential susceptibility to delay-light modification of visual stimulus control (Grant & Roberts, 1976; Maki, Moe, & Bierley, 1977; Roberts & Grant, 1978) and spatial stimulus control (Wilkie, 1983), because the asymmetry occurred regardless of the direction of change in illumination level on probe trials.

During periodic informal observations at the latter stage of training, the experimenter noticed that the birds displayed differential types of delay behavior that may be responsible for the effect of stimulus dimension. On location-matching trials (signaled by houselight-on), Birds 1 and 4 maintained pecking on the key on which the sample had been presented and repeatedly pecked that key when the yellow comparisons appeared on the side keys. On color-matching trials (signaled by houselight-off), Birds 1 and 4 stood in front of the stimulus panel but did not orient toward the keys, at least at the end of the delay (observation was possible only when the houselight was illuminated at the end of the delay). On location-matching trials (signaled by houselight-off), Birds 2 and 3 remained oriented toward and, in some cases, almost touching the sample key

at the end of the delay interval. On color-matching trials (signaled by houselight-on), Birds 2 and 3 pecked (including "air pecks" that stopped short of hitting a key) or looked at all three keys one after another. Number of sample-key pecks emitted during delays and choice latency (not presented in this paper) provided an indirect confirmation of the stereotyped delay behavior. Thus, the houselight condition signaling the relevant matching dimension controlled differential delay behavior.

Many investigators of nonhuman memory have suggested that various types of delay behavior may facilitate accurate responding (e.g., Blough, 1959; Meltzer & Nobbe, 1980; Zentall, Hogan, Howard, & Moore, 1978), and that disrupting or actively preventing these types of behavior leads to performance decrements (Jans & Catania, 1980; Kojima, 1980; Thompson, Van Hemel, Winston, & Pappas, 1983). The topography of our birds' delay behavior on location-matching trials suggests that they may have mediated the delay from presentation of the sample location to the choice response. Such mediational behavior is interpretable as an analogue of rehearsal. In contrast, the topography of our birds' delay behavior on color-matching trials suggests that it may have prevented this sort of rehearsal of the sample location. That is, orientation away from the sample key or orientation to all three keys one after another was unlikely to facilitate control by the sample color. The birds' delay behavior on color-matching trials seems functionally analogous to the behavior of human subjects (e.g., counting backwards by three during the delays) that prevents rehearsal in a short-term memory task (Peterson & Peterson, 1959).

EXPERIMENT 2

The second experiment was conducted to determine whether the performance decrements on probe trials resulted from termination of rehearsal. This question had been examined by earlier directed forgetting studies by manipulating the temporal location of instructional cues within the delay interval (Maki *et al.*, 1981; Stonebraker & Rilling, 1981; Stonebraker *et al.*, 1981). The rationale for these studies was that delaying F cues should result in improved matching accuracy if the

cues terminate rehearsal and if forgetting occurs as a function of time spent in the absence of rehearsal.

In Experiment 2, the houselight condition was changed at the end of the delay interval on infrequent probe trials. Depending on the direction of a change, there were two types of trials. On relevant-irrelevant (R-I) trials, the houselight condition was initially identical to that in regular trials (signaling the relevant dimension) and was then reversed (signaling the irrelevant dimension) shortly before presentation of the comparison stimuli. On irrelevant-relevant (I-R) trials, the houselight condition initially signaled the irrelevant dimension and was then reversed shortly before presentation of the comparison stimuli. Suppose that the houselight condition terminates rehearsal of the irrelevant information of the compound sample (a rehearsal-termination hypothesis). On I-R trials, forgetting of the relevant information (incorrectly cued as irrelevant) should begin to occur immediately after offset of the sample stimulus and continue at least until the houselight condition is changed prior to presentation of the comparison stimuli. The change in the houselight condition may not effectively restore the relevant information, and matching accuracy should be largely reduced. On R-I trials, on the other hand, the bird should perform more accurately.

METHOD

Subjects and Apparatus

The subjects and apparatus were the same as in the previous experiment.

Procedure

After completing Experiment 1, Birds 2 and 4 were trained in the procedure of Experiment 1 with houselight-off signaling color matching and houselight-on signaling location matching. Birds 1 and 3 were trained with houselight-on signaling color matching and houselight-off signaling location matching. Training continued until the same criterion as in Experiment 1 was reached with the maximum delay interval.

A probe session contained eight probe trials in which an illumination change occurred during the delays—a change from signaling the relevant component to signaling the irrelevant

one on R-I trials, and vice versa on I-R trials. Each type of trial occurred four times per session. For Birds 2 and 4 (the maximum delay was 3 s), the houselight was extinguished (signaling color matching) during the first 2 s of the delay and was illuminated (signaling location matching) during the final 1 s of the delay; this was followed by red and green comparisons on R-I color-matching trials or by yellow comparisons on I-R location-matching trials. Similarly, the houselight was illuminated (signaling location matching) during the first 2 s of the delay and was extinguished (signaling color matching) during the final 1 s of the delay on R-I location-matching trials and I-R color-matching trials. For Birds 1 and 3 (the maximum delay was 2 s), the houselight condition was changed 0.5 s prior to presentation of the comparison stimuli. An illumination change for I-R and R-I trials was arranged as in the previous condition. Other procedural details were the same as in Experiment 1. The experiment ended after the 12th probe session.

RESULTS

Figure 2 shows average correct matches in probe sessions for each bird for the different trial types. Location-matching accuracy was markedly reduced on I-R trials for all 4 birds, whereas a lesser reduction occurred on R-I trials. The same tendency was found with color-matching accuracy for Birds 1 and 3, for whom color matching was signaled by houselight-on. In contrast, for Birds 2 and 4, for whom color matching was signaled by houselight-off, accuracy of color matching was substantially reduced on R-I trials but not on I-R trials. A three-way analysis of variance with illumination condition (Birds 2 and 4 vs. Birds 1 and 3), dimension tested (color vs. location), and trial type (regular trials vs. I-R trials vs. R-I trials) was conducted. Significant effects were found for trial type, $F(2, 4) = 14.1$, $p = .01$, the interaction between dimension tested and trial type, $F(2, 4) = 53.0$, $p = .001$, and the interaction between illumination condition, dimension tested, and trial type, $F(2, 4) = 9.0$, $p = .03$. The interaction of dimension tested and trial type confirms the finding that probe performance reduction across 4 birds was greater on I-R trials than on R-I trials when the birds were tested on the location

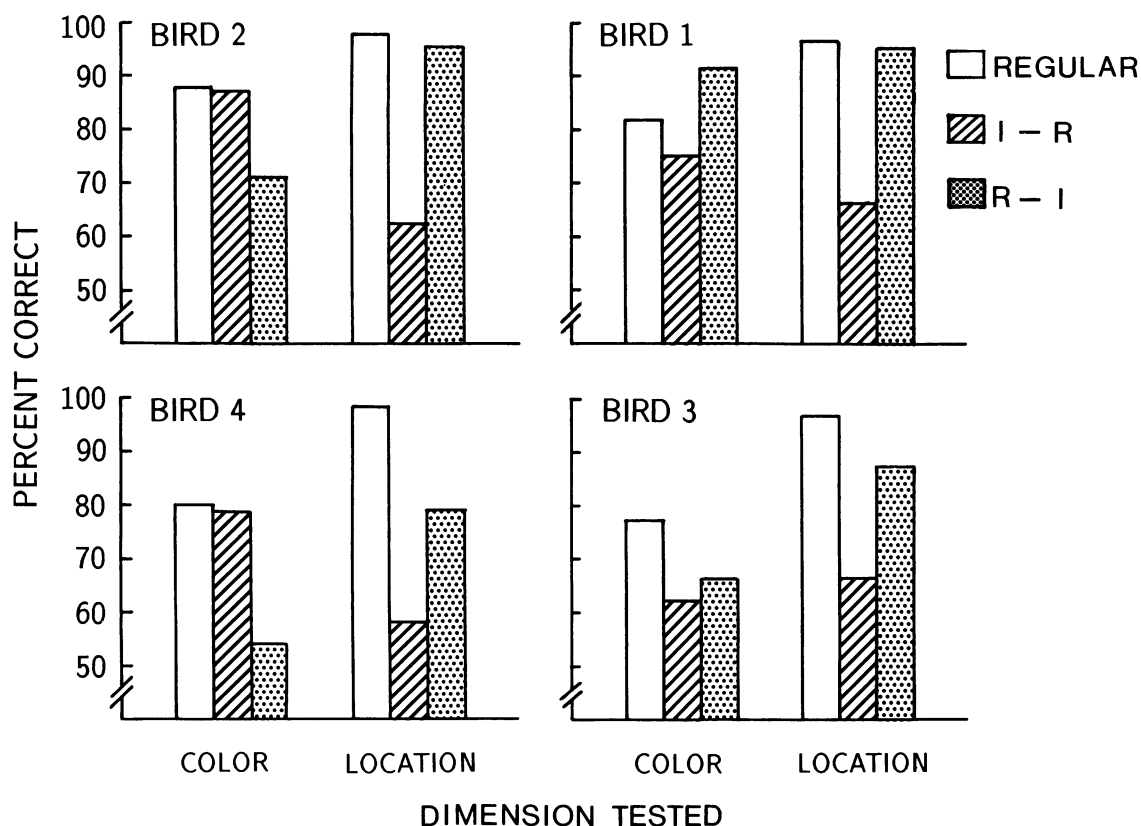


Fig. 2. Percentage of correct matching over 240 regular trials (open bars), 24 I-R trials (hatched bars), and 24 R-I trials (shaded bars) following training in which houselight-off signaled color matching and houselight-on signaled location matching (Birds 2 and 4) or following training in which houselight-on signaled color matching and houselight-off signaled location matching (Birds 1 and 3).

dimension but not when they were tested on the color dimension. The interaction between illumination condition, dimension tested, and trial type shows that the performance decrement over trial types was similar for color and location dimensions for Birds 1 and 3 but differed for color and location dimensions for Birds 2 and 4. The overall effect of dimension tested was not significant, $F(1, 2) = 15.6$, $p = .06$. The effect of illumination condition, $F(1, 2) < 1$, the illumination condition by dimension tested interaction, $F(1, 2) < 1$, and the illumination condition by trial type interaction, $F(2, 4) = 2.0$, $p = .25$, were not significant.

Table 1 shows median response latency for each bird as a function of trial type. The median response latency of color matching was shorter on R-I trials than on I-R trials for Birds 2 and 4 and vice versa for Birds 1 and 3. In contrast, the median response latency of location matching was shorter on I-R trials

than on R-I trials when houselight-on signaled location matching, and vice versa when houselight-off signaled location matching. The Wilcoxon rank-sum test was conducted separately, taking illumination level into account, on the data of color-matching latency and location-matching latency for each bird. The latency on R-I trials differed from that on I-R trials in each case ($p < .05$) on both color-matching and location-matching trials. That is, absolute level of the houselight illumination prior to presentation of the comparison stimuli controlled the birds' choice latency; the birds responded quickly following illuminated delays and relatively slowly following dark delays. Latency on regular trials showed the same tendency (Table 1).

DISCUSSION

The findings on location-matching trials are in accord with the predictions derived from the

rehearsal-termination hypothesis. Location-matching accuracy was greatly reduced on I-R trials but was reduced less on R-I trials.

The findings on color-matching trials did not support a rehearsal-termination hypothesis. A theoretical alternative to this hypothesis is the retrieval-disruption hypothesis. For correct retrieval of the sample color, the house-light condition immediately prior to presentation of the comparison stimuli, rather than that during the delays, should be critical. The retrieval-disruption hypothesis, therefore, predicts less accuracy on R-I trials than on I-R trials, but this was not obtained for Birds 1 and 3.

Instead, a finding consistent among the 4 birds was that a change in illumination level from dark to light prior to presentation of the comparison stimuli (R-I trials for Birds 2 and 4 and I-R trials for Birds 1 and 3) reduced accuracy of color matching. The analysis of choice latency suggests that birds' body orientation or location relative to the keys at the end of the delays was under the control of absolute level of the houselight illumination. Informal observations indicated that the birds approached or oriented toward the key(s) whenever the houselight was turned on shortly before presentation of the comparison stimuli. Such approach behavior may have been associated with errors on the basis of body orientation. In contrast, offset of the houselight shortly before presentation of the comparison stimuli might effectively eliminate or reduce errors that might otherwise occur on the basis of orientation adopted when the houselight had been illuminated.

GENERAL DISCUSSION

The present experiments were designed to determine whether a postsample cue (house-light on or off) signaling the relevant dimension of a compound (color or spatial location) sample stimulus would come to function as a forget cue to reduce stimulus control by the irrelevant dimension of the sample stimulus. According to the rehearsal-disruption hypothesis for directed forgetting, the cues reduce stimulus control by the irrelevant dimension, and performance of any discrimination following an incorrect cue should be impaired. An advantage of the present procedure is that it can test whether the irrelevance of information

Table 1

Median latency (seconds) for each bird as a function of trial type.

Subject		Bird 2	Bird 4	Bird 1	Bird 3
Color	Regular	1.06	1.01	0.90	0.67
	I-R	1.04	0.98	0.97	0.67
	R-I	0.72	0.81	1.08	0.90
Location	Regular	0.36	0.47	0.76	0.72
	I-R	0.62	0.48	0.89	0.75
	R-I	0.74	1.08	0.71	0.57

to performance is sufficient to the establishment of an effective cue to forget. Another important point of this procedure is a theoretical one; any reduction in matching accuracy on incorrectly cued trials cannot be explained by an attention hypothesis. Because delayed choice responding is required on all trials, the instructional cues should not switch attention away from the matching task.

In the present study, it was found that (a) an incorrect cue reliably reduced matching accuracy, regardless of a change in illumination level from dark to light or from light to dark on probe trials relative to that on correctly cued trials; (b) reduction in performance following an incorrect cue was greater for location matching than for color matching; (c) the pigeons oriented toward the sample key during the delays on location-matching trials; (d) the pigeons oriented away from the keys or oriented toward all the keys one after another during the delays on color-matching trials; (e) accuracy of location matching was reduced when the cue initially signaled color matching and then was changed to signal location matching shortly before presentation of the comparison stimuli, whereas matching accuracy was not reduced as much by a change in the opposite direction; and (f) a change from signaling location matching to signaling color matching did not consistently impair accuracy of color matching in the condition in which houselight-off signaled color matching.

The findings summarized above are consistent in suggesting that the cue prompted "remembering" of the sample location when it signaled location matching, whereas the cue promoted "forgetting" of the sample location when it signaled color matching. On the other hand, the cues do not seem to have controlled

forgetting of the sample color in any consistent way. The following findings from Experiment 2 indicate that end-of-delay behavior (e.g., approaching the keys) is responsible for the reduction in color-matching accuracy: (a) Accuracy of color matching was reduced by onset of the houselight shortly before presentation of the comparison stimuli, regardless of type of the relevant dimension signaled by houselight illumination; (b) the onset of the houselight elicited approaching responses to the keys; and (c) the birds accurately performed color matching when the houselight was turned off shortly before presentation of the comparison stimuli. Similarly, the reduced matching accuracy following an incorrect location cue in Experiment 1 may be explained by the fact that the birds tended to make errors on the basis of body orientation.

Based on the observation of our birds' delay behavior, we favor the interpretation that the reduced location-matching accuracy in Experiment 1 supports the rehearsal-termination hypothesis. The finding from Experiment 2 that a change from signaling color matching to signaling location matching consistently reduced accuracy of location matching further supported this notion. Our birds spontaneously developed overt delay behavior that may have interrupted patterns of responding that may otherwise facilitate remembering of the sample location. It should be noted that there were no events controlled by the experimenter that explicitly determined the specific pattern of delay behavior displayed by our birds on color-matching trials.

One may argue that these types of delay behavior are not actual activities of remembering or forgetting of the sample location but are simply interpretable as correlates of some other underlying process. According to this view, an alternative account could explain the cuing effect observed on location dimension. (This possibility was suggested to us by one of the reviewers on an earlier version of this article.) During the delays of location-matching trials, the birds positioned themselves in front of the sample key and responded when it was illuminated yellow. When the yellow comparisons were unexpectedly presented following an incorrect color cue, no specific orientation had been adopted to help guide the choice. The birds could then attempt to retrospectively recall the position of the sample,

but this was not the strategy that they had previously used to solve the location-matching problem. Thus, performance severely suffered. By extending this analysis, the performance decrements in Experiment 2 can be explained if we further assume that the cue presented briefly at the end of the delays does not affect maintenance of birds' posture relative to the sample key.

Although the interpretation proposed above cannot be refuted on the basis of the available data, at least two considerations suggest that it is a less viable account than the directed forgetting account. First, delayed matching of key location in pigeons involves memory-related processes, as shown by the findings that matching accuracy decreases as delay interval increases, sample duration decreases, and the number of locations serving as samples increases (e.g., Wilkie & Summers, 1982). Second, this interpretation cannot reasonably explain the development of the specific delay behavior commonly displayed by all of our birds. We believe that our birds' differential types of delay behavior are not epiphenomenal correlates of some underlying process. A detailed discussion of this issue is offered by Thompson *et al.* (1983).

Although it is not clear how the cuing effect is to be explained, the findings of the present study clearly indicate that the irrelevance of information to performance is critical but not sufficient to produce the cuing effect. If irrelevance is sufficient to the establishment of an effective cue to forget, the cuing effect equivalent to that occurring on the location dimension should have occurred on the color dimension, but it did not. By contrast, Grant (1981) and Grant and Barnett (1991) obtained results suggesting that irrelevance is sufficient to establish an effective cue to forget in a successive matching procedure with red and green fields as the sample stimuli. In a successive matching procedure, the subject is more likely to remember what to do ("peck if upcoming stimulus is red" or "do not peck if it is green" on trials in which the sample was red, and "peck if upcoming stimulus is green" or "do not peck if it is red" on trials in which the sample was green) rather than retrospectively remember whether the sample was red or green (*cf.* Honig & Wasserman, 1981). This was not the case in the color-matching task of the present study. Given these considerations, the difference in

task requirement may account for the discrepant results. If the task of the present study had allowed the birds to prospectively remember what to do depending on the sample color (peck or do not peck), the cuing effect equivalent to that which occurred on the location dimension may have occurred on the color dimension. Further analysis of critical variables that are necessary or sufficient for the cuing effect awaits experiments in which the memory "strategies" are under the experimenter's control.

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